

Cognitive Enhancement: Methods, Ethics, Regulatory Challenges

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Abstract

Cognitive enhancement takes many and diverse forms. In this paper, we survey the current state of the art in cognitive enhancement methods and consider their prospects for the near-term future. We then review some of ethical issues arising from these technologies. We conclude with a discussion of the challenges for public policy and regulation created by present and anticipated methods for cognitive enhancement.

I. Introduction

Cognitive enhancement may be defined as the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems. As cognitive neuroscience has advanced, the list of prospective internal, biological enhancements has steadily expanded.¹ Yet to date, it is progress in computing and information technology that has produced the most dramatic advances in our ability to process information.² External hardware and software supports now routinely give humans beings effective cognitive abilities that in many respects far outstrip those of our biological brains.

Cognition can be defined as the processes an organism uses to organize information. This includes acquiring information (perception), selecting (attention), representing (understanding) and retaining (memory) information, and using it to guide behavior

¹ (Farah, Illes et al. 2004)

² Advances in social organization have also enabled individual minds – through interactions with other people’s minds – to become vastly more effective. Improvements in social organization that are not directly mediated by technology lie outside the scope of this review.

(reasoning and coordination of motor outputs). Interventions to improve cognitive function may be directed at any one of these core faculties.

An intervention that is aimed at correcting a specific pathology or defect of a cognitive subsystem may be characterized as *therapeutic*. An *enhancement* is an intervention that improves a subsystem in some way other than repairing something that is broken or remedying a specific dysfunction. In practice, the distinction between therapy and enhancement is often difficult to make out, and it could be argued that it lacks practical significance. For example, cognitive enhancement of somebody whose natural memory is poor could leave that person with a memory that is still worse than that of another person who has retained a fairly good memory despite suffering from an identifiable pathology, such as early-stage Alzheimer's disease. A cognitively enhanced person, therefore, is not necessarily somebody with particularly high (let alone super-human) cognitive capacities. A cognitively enhanced person, rather, is somebody who has benefited from an intervention that improves the performance of some cognitive subsystem without correcting some specific, identifiable pathology or dysfunction of that subsystem.

The spectrum of cognitive enhancements includes not only medical interventions, but also, as we shall see, psychological interventions (such as learned "tricks" or mental strategies), as well as improvements of external technological and institutional structures that support cognition. A distinguishing feature of cognitive enhancements, however, is that they improve *core cognitive capacities* rather than merely particular narrowly defined skills or domain-specific knowledge.

Most efforts to enhance cognition are of a rather mundane nature, and some have been practiced for thousands of years. The prime example is education and training, where the goal is often not only to impart specific skills or information, but also to improve general mental faculties such as concentration, memory, and critical thinking. Other forms of mental training, such as yoga, martial arts, meditation, and creativity courses are also in common use. Caffeine is widely used to improve alertness. Herbal extracts reputed to improve memory are popular, with sales of *Ginkgo biloba* alone in the order of several hundred million dollars annually in the U.S.³ In an ordinary supermarket we find a staggering number of energy drinks on display, vying for consumers hoping to turbo-charge their brains.

Education and training, as well as the use of external information processing devices, may be labeled as "conventional" means of enhancing cognition. They are often well established and culturally accepted. By contrast, methods of enhancing cognition through "unconventional" means, such as ones involving deliberately created nootropic drugs, gene therapy, or neural implants, are nearly all to be regarded as experimental at the present time. Nevertheless, these unconventional forms of enhancements deserve serious consideration for several reasons:

³ (van Beek 2002)

- They are relatively new, and consequently there does not exist a large body of “received wisdom” about their potential uses, safety, efficacy, or social consequences;
- They could potentially have enormous leverage (consider the cost-benefit ratio of a cheap pill that safely enhances cognition compared to years of extra education);
- They are sometimes controversial;
- They currently face specific regulatory problems, which may impede advances; and
- They may eventually come to have important consequences for society and even, in the longer run, for the future of humankind.

In examining the challenges for public policy with regard to cognitive enhancement, it is important to consider the full range of different possibilities that are becoming available, and their different individual characteristics. From such a comprehensive viewpoint, the inadequacies of some aspects of the current regulatory and policy framework become apparent, as it treats different modes of enhancement differently even though, arguably, there is no good justification for doing so.

One general caveat must be placed in front of the survey that follows. Many of the cognitive enhancement methods being studied today remain highly experimental or have small effect sizes. This makes the present scientific literature a weak guide to their eventual usefulness⁴. Findings need to be repeated in multiple studies and larger clinical trials before they can be fully trusted. It is likely that many enhancement techniques will in the long run prove less efficacious than their current promoters claim. At the same time, the sheer range of enhancement methods suggests that it would be very unlikely that all current methods are ineffective or that future advances will fail to produce an increasingly potent toolbox for enhancing cognition.

II. Methods of Cognitive Enhancement

Education, enriched environments and general health

Education has many benefits beyond higher job status and salary. Longer education reduces the risks of substance abuse, crime and many illnesses while improving quality of life, social connectedness, and political participation⁵. There is also positive feedback between performance on cognitive tests such as IQ tests and scholastic achievement⁶.

Much of what we learn in school is “mental software” for managing various cognitive domains: mathematics, categories of concepts, language, and problem solving in particular subjects. This kind of mental software reduces our mental load through clever encoding, organization, or processing. Instead of memorizing multiplication tables we compress the pattern of arithmetic relationships into simpler rules of multiplication,

⁴ (Ioannidis 2005)

⁵ (Johnston 2004)

⁶ (Winship and Korenman 1997)

which in turn (among very ambitious students) can be organized into efficient mental calculation methods like the Trachtenberg system⁷. Such specific methods have a narrower range of applicability but can dramatically improve performance within a particular domain. They represent a form of crystallized intelligence, distinct from the fluid intelligence of general cognitive abilities and problem solving capacity⁸. The relative ease and utility of improving crystallized intelligence and specific abilities have made them popular targets of internal and external software development. Enhancement of fluid intelligence is more difficult.

Pharmacological cognitive enhancements (nootropics) have physiological effects on the brain. So too do education and other conventional interventions. In fact, conventional interventions often produce more permanent neurological changes than do drugs. Learning to read alters the way language is processed in the brain⁹. Enriched rearing environments have been found to increase dendritic arborisation and to produce synaptic changes, neurogenesis, and improved cognition in animals¹⁰. While analogous controlled experiments cannot easily be done for human children, it is very likely that similar effects would be observed. Stimulation-seeking children, who might be seeking out and creating enriched environments for themselves, score higher on IQ tests and do better at school than less stimulation-seeking children¹¹. This also suggests that interventions, whether environmental or pharmaceutical, that make exploring and learning more appealing to children might improve cognition.

Enriched environments also make brains more resilient to stress and neurotoxins¹². Reducing neurotoxins and preventing bad prenatal environments are simple and widely accepted methods of improving cognitive functioning. These kinds of intervention might be classified as preventative or therapeutic rather than enhancing, but the distinction is blurry. For instance, an optimized intrauterine environment will not only help avoid specific pathology and deficits but is also likely to promote the growth of the developing nervous system in ways that enhance its core capacities.

In brains that have already been damaged, e.g. by lead exposure, nootropics may alleviate some of the cognitive deficits¹³. It is not always clear whether they do so by curing the damage or by amplifying (enhancing) capacities that compensate for the loss, or whether the distinction is even always meaningful. Comparing chronic exposure to cognition enhancing drugs with an enriched rearing environment, one study in rats found that both conditions improved memory performance and produced similar changes in the neural matter. The improvements in the drug-treated group persisted even after cessation of treatment. The combination of drugs and enriched environment did not improve the rats' abilities beyond the improvement provided by one of the interventions alone. This

⁷ (Trachtenberg 2000)

⁸ (Cattell 1987)

⁹ (Pettersson, Reis et al. 2000)

¹⁰ (Walsh, Budtz-Olsen et al. 1969; Greenough, Wt and Volkmar 1973) (Diamond, Johnson et al. 1975) (Nilsson, Perfilieva et al. 1999)

¹¹ (Raine, Reynolds et al. 2002)

¹² (Schneider, Lee et al. 2001)

¹³ (Zhou and Suszkiw 2004)

suggests that both interventions produced a more robust and plastic neural structure capable of learning more efficiently.

Improving general health has cognition-enhancing effects. Many health problems act as distractors or directly impair cognition¹⁴. Improving sleep, immune function, and general conditioning promotes cognitive functioning. Bouts of exercise have been shown to improve temporarily various cognitive capacities, the size of the effect depending on the type and intensity of the exercise¹⁵. Long-term exercise also improves cognition, possibly through a combination of increased blood supply to the brain and the release of nerve growth factors¹⁶.

Mental training

Mental training and visualization techniques are widely practiced in elite sport¹⁷ and rehabilitation¹⁸, with apparently good effects. Users vividly imagine themselves performing a task (running a race, going to a store), repeatedly imagining every movement and how it would feel. A likely explanation for the efficacy of such exercises is that they activate the neural networks involved in executing a skill at the same time as the performance criteria for the task is held in close attention, optimizing neural plasticity and appropriate neural reorganization.

General mental activity—“working the brain muscle”—can improve performance¹⁹ and long-term health²⁰, while relaxation techniques can help regulate the activation of the brain²¹. It has been suggested that the Flynn-effect²², a secular increase in raw intelligence test scores by 2.5 IQ points per decade in most western countries, is attributable to increased demands of certain forms of abstract and visuospatial cognition in modern society and schooling, although improved nutrition and health status may also play a part²³. On the whole, however, the Flynn effect seems to reflect a change in which specific forms of intelligence are developed, rather than an increase in general fluid intelligence.

The classic form of cognitive enhancement software is learned strategies to memorize information. Such methods have been used since antiquity with much success²⁴. One such classic strategy is “the method of loci”. The user visualizes a building, either real or imaginary, and in her imagination she walks from room to room, depositing imaginary objects that evoke natural associations to the subject matter that she is memorizing.

¹⁴ (Schillerstrom, Horton et al. 2005)

¹⁵ (Tomprowski 2003)

¹⁶ (Vaynman and Gomez-Pinilla 2005)

¹⁷ (Feltz and Landers 1983)

¹⁸ (Jackson, Doyon et al. 2004)

¹⁹ (Nyberg, Sandblom et al. 2003)

²⁰ (Barnes, Tager et al. 2004)

²¹ (Nava, Landau et al. 2004)

²² (Flynn 1987)

²³ (Neisser 1997) (Blair, Gamson et al. 2005)

²⁴ (Yates 1966) (Patten 1990)

During retrieval, the user retraces her imaginary steps, and the sequence of memorized information is recalled when she “sees” the objects she placed along the route. This technique harnesses the brain’s spatial navigation system to remember objects or propositional contents. Other memory techniques makes use of rhyming or the fact that we more easily recall dramatic, colorful, or emotional scenes, which can serve as proxies for items that are more difficult to retain, such as numbers or letters. The early memory arts were often used as a substitute for written text or to memorize speeches. Today, memory techniques tend to be used in service of everyday needs such as remembering door codes, passwords, shopping lists, and by students who need to memorize names, dates, and terms when preparing for exams²⁵.

One study which compared exceptional memorizers (participants in the World Memory Championships) with normal subjects found no systematic differences in brain anatomy²⁶. However, it found differences in activity patterns during memorization, likely reflecting the use of a deliberate encoding strategy. Areas of the brain involved in spatial representation and navigation were disproportionately activated in the skilled memorizers, regardless of whether the items to be memorized were numbers, faces, or the shapes of snowflakes. Asked about their memory strategies, nearly all the memorizers reported using the method of loci.

In general, it is possible to attain very high memory performance on specific types of material using memory techniques. They provide the greatest performance enhancement for meaningless or unrelated information, such as sequences of numbers, but they do not appear to help in complex everyday activities²⁷.

There exists a vast array of mental techniques alleged to boost various skills, such as creativity training, speed reading methods²⁸, and mind-maps²⁹. It is unclear how widespread the use of such techniques is, and in most cases there is a lack of good data about their efficacy. Even if a technique improves performance on some task under laboratory conditions, it does not follow that the technique is practically useful. In order for a technique to significantly benefit a person, it would have to be effectively integrated into her daily life.

Drugs

Stimulant drugs such as nicotine and caffeine have long been used to improve cognition. In the case of nicotine a complex interaction with attention and memory occurs³⁰, while caffeine reduces tiredness³¹. In more recent years, a wide array of drugs have been developed that affect cognition³².

²⁵ (Minninger 1997) (Lorrayne 1996)

²⁶ (Maguire, Valentine et al. 2003)

²⁷ (Ericsson 2003)

²⁸ (Calef, Pieper et al. 1999).

²⁹ (Buzan 1982) (Farrand, Hussain et al. 2002)

³⁰ (Warburton 1992; Newhouse, Potter et al. 2004; Rusted, Trawley et al. 2005)

³¹ (Lieberman 2001; Smith, Brice et al. 2003; Tieges, Richard Ridderinkhof et al. 2004)

³² (Farah, Illes et al. 2004)

Lashley observed in 1917 that strychnine facilitates learning in rats³³. Since then several families of memory enhancing drugs affecting different aspects of long-term memory have been discovered. They include stimulants³⁴, nutrients³⁵ and hormones³⁶, cholinergic agonists³⁷, the piracetam family³⁸, ampakines³⁹, and consolidation enhancers⁴⁰.

Diet, and dietary supplements, can affect cognition. In order to maintain optimal functioning, the brain requires a continuous supply of glucose, its major energy source⁴¹. Increases in glucose availability, from the ingestion of sugars or the release of the acute stress hormone norepinephrine, improve memory⁴², with the effects being particularly pronounced in demanding tasks⁴³. Creatine, a nutrient that improves energy availability, also appears to benefit overall cognitive performance⁴⁴ and reduce mental fatigue⁴⁵. Besides being an energy source, food can contribute to cognition by providing amino acids needed in the production of neurotransmitters, which is particularly important during periods of stress or sustained concentration⁴⁶. There is also evidence that micronutrient supplementation increases nonverbal intelligence in some children. This effect might be due to correction of occasional deficiencies rather than a general enhancing action⁴⁷.

Stimulants enhance memory by increasing neuronal activation or by releasing neuromodulators, facilitating the synaptic changes that underlie learning. The earliest enhancer drugs were mainly nonspecific stimulants and nutrients. In antiquity, for example, honey water (hydromel) was used for doping purposes.

Advances in the scientific understanding of memory enabled the development of drugs with more specific actions, such as drugs stimulating the cholinergic system, which appears to gate attention and memory encoding. Current interest is focused on intervening in the process of permanent encoding in the synapses, a process which has been greatly elucidated in recent years and is a promising target for drug development. The goal is to develop drugs that not only allow the brain to learn quickly, but which also facilitate selective retention of the information that has been learned. Several experimental substances have been shown to improve performance in particular memory tests. It is not yet known whether these drugs also promote useful learning in real-life

³³ (Lashley 1917)

³⁴ (Lee and Ma 1995) (Soetens, Dhooge et al. 1993; Soetens, Casaer et al. 1995)

³⁵ (Korol and Gold 1998) (Foster, Lidder et al. 1998) (Meikle, Riby et al. 2005) (Winder and Borrill 1998)

³⁶ (Gulpinar and Yegen 2004)

³⁷ (Iversen 1998) (Power, Vazdarjanova et al. 2003) (Freo, Ricciardi et al. 2005)

³⁸ (Mondadori 1996)

³⁹ (Lynch 1998) (Ingvar, AmbrosIngerson et al. 1997)

⁴⁰ (Lynch 2002)

⁴¹ (Fox, Raichle et al. 1988)

⁴² (Wenk 1989; Foster, Lidder et al. 1998)

⁴³ (Sunram-Lea, Foster et al. 2002)

⁴⁴ (Rae, Digney et al. 2003)

⁴⁵ (Watanabe, Kato et al. 2002; McMorris, Harris et al. 2006)

⁴⁶ (Banderet and Lieberman 1989; Deijen, Wientjes et al. 1999; Lieberman 2003)

⁴⁷ (Benton 2001)

situations, but beneficial enhancement of memory through pharmacological means is likely to be possible.

Pharmacological agents might be useful not only for increasing memory retention but also for unlearning phobias and addictions⁴⁸. Potentially, the combination of different drugs administered at different times could give users a more fine-grained control of their learning processes, perhaps even the ability to deliberately select specific memories that they want to retain or get rid of.

Even common, traditional and unregulated herbs and spices such as sage can improve memory and mood through chemical effects⁴⁹. While less powerful than those of dedicated cholinesterase inhibitors, such effects illustrate that attempts to control access to cognition enhancing substances would be problematic. Even chewing gum appears to affect memory, possibly by heightening arousal or blood sugar⁵⁰.

Working memory can be modulated by a variety of drugs. Drugs that stimulate the dopamine system have demonstrated effects, as do cholinergic drugs (possibly through improved encoding)⁵¹. Modafinil has been shown to enhance working memory in healthy test subjects, especially at harder task difficulties and for lower-performing subjects⁵². (Similar findings of greater improvements among low performers were also seen among the dopaminergic drugs, and this might be a general pattern for many cognitive enhancers.) Modafinil has been found to increase forward and backward digit span, visual pattern recognition memory, spatial planning, and reaction time/latency on different working memory tasks⁵³. The mode of action of this drug is not yet understood, but part of what seems to happen is that modafinil enhances adaptive response inhibition, making the subjects evaluate a problem more thoroughly before responding, thereby improving performance accuracy. The working memory effects might thus be part of a more general enhancement of executive function.

Modafinil was originally developed as a treatment for narcolepsy, and can be used to reduce performance decrements due to sleep loss with apparently small side effects and little risk of dependency⁵⁴. The drug improved attention and working memory in sleep-deprived physicians⁵⁵ and aviators⁵⁶. Naps are more effective in maintaining performance than modafinil and amphetamine during long (48h) periods of sleep deprivation, while the reverse holds for short (24h) periods of sleep deprivation. Naps followed by a modafinil dose may be more effective than either one on its own⁵⁷. These results, together with studies on hormones like melatonin which can control sleep

⁴⁸ (Pitman, Sanders et al. 2002) (Hofmann, Meuret et al. 2006) (Ressler, Rothbaum et al. 2004)

⁴⁹ (Kennedy, Pace et al. 2006)

⁵⁰ (Wilkinson, Scholey et al. 2002)

⁵¹ (Barch 2004)

⁵² (Muller, Steffenhagen et al. 2004)

⁵³ (Turner, Robbins et al. 2003)

⁵⁴ (Teitelman 2001) (Myrick, Malcolm et al. 2004)

⁵⁵ (Gill, Haerich et al. 2006)

⁵⁶ (Caldwell, Caldwell et al. 2000)

⁵⁷ (Batejat and Lagarde 1999)

rhythms⁵⁸, suggest that drugs can enable fine-tuning of alertness patterns to improve task performance under demanding circumstances or disturbed sleep cycles.

There also exist drugs that influence how the cerebral cortex reorganizes in response to damage or training. Noradrenergic agonists such as amphetamine have been shown to promote faster recovery of function after a brain lesion when combined with training⁵⁹, and to improve learning of an artificial language⁶⁰. A likely explanation is that higher excitability increases cortical plasticity, in turn leading to synaptic sprouting and remodeling⁶¹. An alternative to pharmacologic increase of neuromodulation is to electrically stimulate the neuromodulatory centers that normally control plasticity through attention or reward. In monkey experiments this produced faster cortical reorganization⁶².

Transcranial magnetic stimulation

Transcranial magnetic stimulation (TMS) can increase or decrease the excitability of the cortex, thereby changing its level of plasticity⁶³. TMS of the motor cortex that increased its excitability improved performance in a procedural learning task⁶⁴. TMS in suitable areas has also been found beneficial in a motor task⁶⁵, motor learning⁶⁶, visuo-motor coordination tasks⁶⁷, working memory⁶⁸, finger sequence tapping⁶⁹, classification⁷⁰ and even declarative memory consolidation during sleep⁷¹. Snyder et al. claim to have demonstrated how TMS inhibiting anterior brain areas could change the drawing style of normal subjects into a more concrete style and improve spell-checking abilities, presumably by reducing top-down semantic control⁷². While TMS appears to be quite versatile and non-invasive, there are risks of triggering epileptic seizures, and the effects of long-term use are not known. Moreover, individual brain differences may necessitate much adjustment before it can be used to improve specific cognitive capacities. It is still doubtful whether TMS will ever be a practically useful enhancement method.

Genetic modifications

Genetic memory enhancement has been demonstrated in rats and mice. In normal animals, during maturation, expression of the NR2B subunit of the NMDA receptor is

⁵⁸ (Cardinali, Brusco et al. 2002)

⁵⁹ (Gladstone and Black 2000)

⁶⁰ (Breitenstein, Wailke et al. 2004)

⁶¹ (Stroemer, Kent et al. 1998) (Goldstein 1999)

⁶² (Bao, Chan et al. 2001) (Kilgard and Merzenich 1998)

⁶³ (Hummel and Cohen 2005)

⁶⁴ (Pascual-Leone, Tarazona et al. 1999)

⁶⁵ (Butefisch, Khurana et al. 2004)

⁶⁶ (Nitsche, Schauenburg et al. 2003)

⁶⁷ (Antal, Nitsche et al. 2004) (Antal, Nitsche et al. 2004)

⁶⁸ (Fregni, Boggio et al. 2005)

⁶⁹ (Kobayashi, Hutchinson et al. 2004)

⁷⁰ (Kincses, Antal et al. 2004)

⁷¹ (Marshall, Molle et al. 2004)

⁷² (Snyder, Mulcahy et al. 2003) (Snyder, T. et al. 2004)

gradually replaced with expression of the NR2A subunit. This might be linked to the lower brain plasticity of adult animals. Tsien et al.⁷³ modified mice to overexpress the NR2B subunit. The NR2B “Doogie” mice showed improved memory performance, in terms of both acquisition and retention. This included unlearning of fear conditioning, which is believed to be due to the learning of a secondary memory⁷⁴. The modification also made the mice more sensitive to certain forms of pain, suggesting a non-trivial trade-off between two potential enhancement goals⁷⁵. Pain sensitivity could be countered by administration of an analgesic.

Increased amounts of brain growth factors⁷⁶ and the signal transduction protein adenylyl cyclase⁷⁷ have also produced memory improvements. These modifications had different enhancing effects. Unlearning took longer for these modified mice than for unmodified mice, while the mice in the abovementioned Tsien study had faster than normal unlearning. Different memory tasks were also differently affected: the cyclase mice had enhanced recognition memory but not improved context or cue learning. Another study found that mice with a deleted *cbl-b* gene had normal learning but enhanced long-term retention, presumably indicating that the gene is a negative regulator of memory⁷⁸. These enhancements may be due to changes in neural plasticity during the learning task itself, or to ontogenetic changes in brain development that promote subsequent learning or retention.

The cellular machinery of memory appears to be highly conserved in evolution, making interventions demonstrated to work in animal models likely to have close counterparts in humans⁷⁹.

Genetic studies have also found genes in humans whose variations account for up to 5% of memory performance⁸⁰. These include the genes for the NMDA receptor and adenylyl cyclase that were mentioned above, as well as genes involved in other stages of the synaptic signal cascade. These are obvious targets for enhancement.

Given these early results, it seems likely that there exist many potential genetic interventions that would directly or indirectly improve aspects of memory. If it turns out that the beneficial effects of the treatments are not due to changes in development, then presumably some of the effects can be achieved by supplying the brain with the substances produced by the memory genes without resorting to genetic modification. But genetic modification would make the individual independent of an external drug supply and would guarantee that the substances end up in the right place.

⁷³ (Tang, Shimizu et al. 1999)

⁷⁴ (Falls, Miserendino et al. 1992)

⁷⁵ (Wei, Wang et al. 2001)

⁷⁶ (Routtenberg, Cantalops et al. 2000)

⁷⁷ (Wang, Ferguson et al. 2004)

⁷⁸ (Tan, Liu et al. 2006)

⁷⁹ (Bailey, Bartsch et al. 1996) (Edelhoff, Villacres et al. 1995)

⁸⁰ (de Quervain and Papassotiropoulos 2006)

Studies of the genetics of intelligence suggest that there is a large number of genetic variations affecting individual intelligence, but each accounting for only a very small fraction (<1%) of the variance between individuals⁸¹. This would indicate that genetic enhancement of intelligence through direct insertion of a few beneficial alleles is unlikely to have a big enhancing effect. It is possible, however, that some alleles that are rare in the human population could have larger effects on intelligence, both negative and positive⁸².

Prenatal and perinatal enhancement

A notable form of chemical enhancement is pre- and perinatal enhancement. Administering choline supplementation to pregnant rats improved the performance of their pups, apparently as a result of changes in neural development⁸³. Given the ready availability of choline supplements, such prenatal enhancement may already (inadvertently) be taking place in human populations. Supplementation of a mother's diet during late pregnancy and 3 months postpartum with long chained fatty acids has also been shown to improve cognitive performance in human children⁸⁴. Deliberate changes of maternal diet might be regarded as part of the cognitive enhancement spectrum. At present, recommendations to mothers are mostly aimed at promoting a diet that avoids specific harms and deficits, but the growing emphasis on boosting "good fats" and the use of enriched infant formulas point towards enhancement.

External hardware and software systems

Some approaches in human-computer interaction are explicitly aimed at cognitive enhancement⁸⁵. External hardware is of course already used to amplify cognitive abilities, be it pen and paper, calculators, or personal computers. Many common pieces of software act as cognition-enhancing environments, where the software helps display information, keep multiple items in memory, and perform routine tasks. Data mining and information visualization tools process and make graspable enormous amounts of data that our perceptual systems cannot handle. Other tools such as expert systems, symbolic math programs, decision support software, and search agents amplify specific skills and capacities.

What is new is the growing interest in creating intimate links between the external systems and the human user through better interaction. The software becomes less an external tool and more of a mediating "exoself". This can be achieved through mediation, embedding the human within an augmenting "shell" such as wearable computers⁸⁶ or virtual reality, or through smart environments in which objects are given extended capabilities. An example is the vision of "ubiquitous computing", in which objects would

⁸¹ (Craig and Plomin 2006)

⁸² A possible example is suggested in (Cochran, Hardy et al. 2006), where it is predicted that heterozygosity for Tay-Sachs' disease should increase IQ by about 5 points.

⁸³ (Meck, Smith et al. 1988) (Mellott, Williams et al. 2004)

⁸⁴ (Helland, Smith et al. 2003)

⁸⁵ (Engelbart 1962)

⁸⁶ (Mann 2001) (Mann and Niedzviecki 2001)

be equipped with unique identities and given ability to communicate with and actively support the user⁸⁷. A well-designed environment can enhance proactive memory⁸⁸ by deliberately bringing previous intentions to mind in the right context.

Another form of memory-enhancing exoself software is remembrance agents⁸⁹, software agents that act as a vastly extended associative memory. The agents have access to a database of information such as a user's files, email correspondence etc., which they use to suggest relevant documents based on the current context. Other exoself applications include additions to vision⁹⁰, team coordination⁹¹, face recognition⁹², mechanical prediction⁹³, and the recording of emotionally significant events⁹⁴.

Given the availability of external memory support, from writing to wearable computers, it is likely that the crucial form of memory demand on humans in the future will increasingly be the ability to link information into usable concepts, associations, and skills rather than the ability to memorize large amounts of raw data. Storage and retrieval functions can often be offloaded from the brain, while the knowledge, strategies, and associations linking the data to skilled cognition cannot so far be outsourced to computers to the same extent.

Brain-Computer interfaces

Wearable computers and PDAs are already intimate devices worn on the body, but there have been proposals for even tighter interfaces. Direct control of external devices through brain activity has been studied with some success for the last 40 years, although it remains a very low bandwidth form of signalling⁹⁵.

The most dramatic potential internal hardware enhancements are brain-computer interfaces. Development is rapid, both on the hardware side, where multielectrode recordings from more than 300 electrodes permanently implanted in the brain are currently state-of-the art, and on the software side, with computers learning to interpret the signals and commands⁹⁶. Early experiments on humans have shown that it is possible for profoundly paralyzed patients to control a computer cursor using just a single electrode⁹⁷ implanted in the brain, and experiments by Patil et al. have demonstrated that the kind of multielectrode recording devices used in monkeys would most likely function in humans too⁹⁸. Experiments in localized chemical release from implanted chips also

⁸⁷ (Weiser 1991)

⁸⁸ (Sellen, Louie et al. 1996)

⁸⁹ (Rhodes and Starner 1996)

⁹⁰ (Mann 1997)

⁹¹ (Fan, Sun et al. 2005) (Fan, Sun et al. 2005)

⁹² (Singletary and Starner 2000)

⁹³ (Jebara, Eyster et al. 1997)

⁹⁴ (Healey and Picard 1998)

⁹⁵ (Wolpaw, Birbaumer et al. 2000)

⁹⁶ (Nicoletis, Dimitrov et al. 2003) (Shenoy, Meeker et al. 2003) (Carmena, Lebedev et al. 2003)

⁹⁷ (Kennedy and Bakay 1998)

⁹⁸ (Patil, Carmena et al. 2004)

suggest the possibility of using neural growth factors to promote patterned local growth and interfacing⁹⁹.

Cochlear implants are already widely used, and there is ongoing research in artificial retinas¹⁰⁰ and functional electric stimulation for paralysis treatment¹⁰¹. These implants are intended to ameliorate functional deficits and are unlikely to be attractive for healthy people in the foreseeable future. But the digital parts of the implant could in principle be connected to any kind of external software and hardware. This could enable enhancing uses such as access to software tools, the Internet, and virtual reality applications. In a demonstration project, a healthy volunteer has been enabled to control a robotic arm using tactile feedback, both in direct adjacency and remotely, and to perform simple direct neural communication with another implant¹⁰². Non-disabled people, however, could most likely achieve the essentially same functionality more cheaply, safely, and effectively through eyes, finger, and voice control.

Collective intelligence

Much of human cognition is distributed across many minds. Such distributed cognition can be enhanced through the development and use of more efficient tools and methods of intellectual collaboration. The World Wide Web and e-mail are among the most powerful kinds of cognitive enhancement software developed to date. Through the use of such social software, the distributed intelligence of large groups can be shared and harnessed for specific purposes¹⁰³.

Connected systems allow many people to collaborate in the construction of shared knowledge and solutions. Usually, the more individuals that connect, the more powerful the system becomes¹⁰⁴. The information in such systems is stored not just in individual documents but also in their interrelations. When such interconnected information resources exist, automated systems such as search engines¹⁰⁵ can often radically improve our ability to extract useful information from them.

Lowered coordination costs enable larger groups to work on common projects. Groups of volunteers with shared interests, such as amateur journalist “bloggers” and open source programmers, have demonstrated that they can successfully complete large and highly complex projects, such as online political campaigns, the Wikipedia encyclopedia, and the Linux operating system. Systems for online collaboration can incorporate efficient error correction¹⁰⁶, enabling incremental improvement of product quality over time.

⁹⁹ (Peterman, Noolandi et al. 2004)

¹⁰⁰ (Alteheld, Roessler et al. 2004)

¹⁰¹ (von Wild, Rabischong et al. 2002)

¹⁰² (Warwick, Gasson et al. 2003)

¹⁰³ (Surowiecki 2004)

¹⁰⁴ (Drexler 1991)

¹⁰⁵ (Kleinberg 1999)

¹⁰⁶ (Raymond 2001; Giles 2005)

One powerful technique of knowledge aggregation is prediction markets (also known as “information markets” or “idea futures markets”). In such a market, participants trade in predictions of future events. The prices of these bets tend to reflect the best information available about the probability of whether the events will occur¹⁰⁷. Such markets appear to be self-correcting and resilient, and have been shown to outperform alternative methods of generating probabilistic forecasts, such as opinion polls and expert panels¹⁰⁸.

III. Ethical Issues

Safety

Safety concerns tend to focus on medical risks of internal biological enhancements. Yet risks accompany any intervention, not just biomedical procedures. External software enhancements raise safety issues such as privacy and data protection. Similar issues can arise in some enhancements focusing on collaborative intelligence. The latter might also create unique kinds of risks arising from emergent phenomena in large networks of interacting agents – witness the “flame wars” into which some email lists are prone to erupt, creating stress and unpleasantness for everyone involved. Psychological techniques and training are generally regarded as safe, but to the extent that their long-term use have significant effects on neural organization, they can pose subtle but substantial risks to the user.

Even education is a risky enhancement method. Education can enhance cognitive skills and capacities, but it can also create fanatics, dogmatists, sophistic arguers, skilled rationalizers, cynical manipulators, and indoctrinated, prejudiced, confused, or selfishly calculating minds. Even high-quality education that includes training in formal methods and critical thinking can have problematic effects. For instance, several studies indicate that the study of economics make students on average more selfish than they were before.¹⁰⁹ (Higher education may also increase the risk of becoming a professor or university don – a profession characterized by E. Friedell as involving a slow metabolism, a sluggish bowel, a penchant for gradualist doctrines, and pedantry¹¹⁰.)

One could argue that the risks from education are fundamentally different from certain other categories of risk, such as medical risks. A student who becomes a fanatic or selfishly calculating does so, one argument runs, through their own choice and their deliberate acceptance of, or reaction to, the taught material. In contrast, a drug’s action on the nervous system is more direct, unmediated by propositional beliefs or conscious deliberation. This argument, however, is not entirely convincing. Educational enhancements are widely applied to subjects who are too young to give informed consent to the procedure, and who are unable critically to evaluate what they are being taught. Even among more advanced students, it is implausible that all the effects of education are

¹⁰⁷ (Hanson, Polk et al. 2003)

¹⁰⁸ (Hanson, Opre et al. 2006)

¹⁰⁹ (Frank, Gilovich et al. 1993; Rubinstein 2005)

¹¹⁰ Cited from (Kolnai 1976)

mediated by rational deliberation. Much is simply “absorbed” through subconscious emulation and as a side-effect of how information is presented. Cognitive habits and inclinations acquired from education often have life-long sequelae.

Nevertheless, it is in the area of medical enhancement that safety issues are likely to be most salient. Since the current medical risk system is based on comparing treatment risk with the expected benefit of reduced morbidity risk from successful treatment, it is strongly risk averse in the case of enhancements that do not reduce morbidity risk and whose utility to the patient may be entirely non-therapeutic, highly subjective, and context dependent. Yet precedents for a different risk model can be found, for example in use of cosmetic surgery. The consensus is that patient autonomy overrides at least minor medical risks even when the procedure does not reduce or prevent morbidity. A similar model could be used in the case of medical cognitive enhancements, with the user being allowed to decide whether the benefits outweigh the potential risks, based on advice from medical professionals and her own estimates of how the intervention might affect her personal goals and her way of life. The risks of chronic use of a cognition enhancing drug include the possibility of both medical side effects and effects more directly tied to the drug’s intended function. For instance, a memory enhancer could, by exerting its intended effect, increase the number of trivial “junk” memories retained, which might be undesirable. It will often not be possible accurately to quantify these potential risks of long-term use beforehand, so there is a limit to how much guidance a user can expect to obtain from medical experts. Nor are medical experts necessarily in a position to judge whether, for a particular user, the benefits are worth the risks.

The development of cognitive enhancers may also face problems in terms of acceptable risk to test subjects. The reliability of research is another issue. Many of the cognition-enhancing interventions show small effect sizes. This may necessitate very large epidemiological studies, possibly exposing large groups to unforeseen risks.

Some enhancements may make us dependent on outside technology, infrastructure, or drugs. If the supply is interrupted, users may suffer withdrawal symptoms or impairments. Is this sufficient reason to discourage some enhancements? Is a life dependent on external support structures less worth living, or less dignified, than an independent, unassisted, or more “natural” life?

The purpose of medicine

One common concern about enhancements in the biomedical sphere is that they go beyond the purpose of medicine. The debate over whether it is possible to draw a line between therapy and enhancement, and if so where, is extensive. Regardless of this, it is clear that medicine does encompass many treatments not intended to cure, prevent, or ameliorate illness, such as plastic surgery and contraceptive medication, which are accepted. There are also many forms of enhancement that do not fit into the medical framework, such as psychological techniques and diet, but which nevertheless produce medical effects. Even if a boundary between therapy and enhancement could be agreed, it is unclear that it would have any normative significance.

A related concern is that resort to medical or technological “fixes” will become a displacement for efforts to confront deeper social or personal problems. Especially Ritalin and other ADHD medications (many of which function as cognitive enhancers in healthy subjects) have been fiercely debated in the past, some arguing that these medications are often used to paper over the failings of the education system by making rowdy boys calmer rather than developing teaching methods that can accommodate a wider range of individual learning styles and needs. However, if modern society requires much more study and intellectual concentration than was typical for our species in its environment of evolutionary adaptation, then it is unsurprising that many people today struggle to meet the demands of the school or the workplace. Technological self-modification and the use of cognitive enhancement methods can be seen as an extension of the human species’ ability to adapt to its environment.

Enhancements for minors and incompetent individuals

Young children are not in a position to give informed consent for medical interventions. The same holds true for individuals with severe mental disability, and for non-human animals. Who should be making decisions about the use of enhancement on behalf of incompetent subjects? On what grounds should these decisions be made? Is there a special obligation to help some incompetent subjects become competent agents capable of autonomous reasoning? One might also ask, supposing it became technologically feasible, whether some animals (such as the great apes) ought to be given cognitive enhancements (“uplifted”) to enable them to function at a level closer to that of normal humans.

Procreative choice and eugenics

Some enhancements do not increase the capacity of any existing being but rather cause a new person to come into existence with greater capacities than some other possible person would have had who could have come into existence instead. This is what happens in embryo selection¹¹¹. At present, preimplantation genetic diagnosis is used mainly to select out embryos with genetic disease, and occasionally for the purpose of sex selection. In the future, however, it might become possible to test for a variety of genes known to correlate with desirable attributes, including cognitive capacity. Genetic engineering might also be used to remove or insert genes into a zygote or an early embryo. In some cases, it might be unclear whether the outcome is a new individual or the same individual with a genetic modification.

It has been argued that when parents are able to do so without significant cost or inconvenience to themselves, they have an obligation to select – out of the possible children they could have – the one that they judge would have the best prospects of having a good life. This has been termed the Principle of Procreative Beneficence¹¹².

¹¹¹ (Glover 1984)

¹¹² (Savulescu 2001)

Critics of genetic enhancements have asserted that the creation of “designer babies” will corrupt parents, who will come to view their children as mere products, subject to being evaluated according to standards of quality control rather than unconditionally accepted and loved. Are we prepared to sacrifice on the altar of consumerism even those deep values that are embodied in traditional relationships between child and parents? Is the quest for perfection worth this cultural and moral cost?¹¹³ There is, however, currently no clear evidence for the hypothesis that parents making use of enhancement options in procreation would become incapable of accepting and loving their children. When *in vitro* fertilization was first introduced, bioconservative critics predicted similar psychological harms which, fortunately, did not materialize.

Some disability advocates have voiced concern that genetic enhancement could express a negative attitude to people with disabilities, who might face increased discrimination as a result. This objection appears to apply equally to the use of preimplantation genetic diagnosis to screen embryos for genetic abnormalities, in that abnormal embryos are seen as unworthy of being allowed to develop.

Some have argued that genetic selection and genetic enhancement would constitute a kind of “tyranny of the living over the unborn,”¹¹⁴. Others have responded that a child is no freer if her genes are determined by chance than if they are determined by parental choice. Furthermore, some enhancements would increase the offspring’s capacity for autonomous agency¹¹⁵.

There are also questions about the relations of germ-line interventions to the now discredited eugenics programs of the last century. Other interventions that may affect the next generation, such as prenatal surgery, improvements in maternal nutrition, and screening for genetic abnormalities, have not, however, evoked the same concerns. It is important to determine the reason for this, and to examine whether there are ethically relevant differences between what may appear to be simply various means to the same end. Contemporary defenders of so-called “liberal eugenics” emphasize that they are not supporting coercive state programs but rather that parents should be allowed to make these choices themselves and that procreative freedom must be protected¹¹⁶. Several issues still arise here, such as whether the state should subsidize enhancements for parents who cannot afford them, and what protection against harmful interventions the state could impose without unduly infringing on reproductive liberty.

Authenticity

The issue of authenticity has many sides. One is the idea that native or achieved excellence has a higher worth than talent that is bought. If cognitive abilities are for sale, in the form of a pill or some external aid, would that reduce their value and make them less admirable? Would it in some sense make the abilities less genuinely *ours*? Related to

¹¹³ (Kass 2002)

¹¹⁴ (Jonas 1985)

¹¹⁵ (Fukuyama 2002)

¹¹⁶ (Agar 2004)

this, one might think that if excellence is achieved mostly through hard work, then genetic differences and parental class play a smaller role in determining success. But if there were shortcuts to excellence then access to such shortcuts would instead become the determining factor of success and failure.

In many cases, however, shortcuts to excellence are tolerated. We do not denounce athletes for wearing protective (and performance enhancing) shoes, since they enable the athletes to concentrate on interesting talents rather than on developing thick soles. In many elementary schools, calculators are disallowed in mathematics lessons, where the goal is to understand basic arithmetic, but they are allowed and increasingly necessary in the higher grades. The basics have by then been mastered, and the goal becomes to understand more advanced topics. These examples illustrate that cognitive enhancement aimed at extending and completing a person's talents may promote authenticity by offloading irrelevant, repetitive, or boring tasks and enabling a person to concentrate on more complex challenges that relate in more interesting ways to her goals and interests.

Another side of the authenticity issue is the extent to which our "free choices" are manipulated by advertisers or are slavishly bound to reigning fashions by our desire to conform in order to gain social acceptance. If enhancements are added to the "must-haves" of a modern consumer, does that mean that our bodies and minds would come even more directly under the dominion of external and therefore "inauthentic" drivers than is currently the case? Some critics see human enhancement in general as expressive of a technocratic mindset, which threatens to "flatten our souls", sap our moral fiber, lower our aspirations, weaken our loves and attachments, lull our spiritual yearnings, undermine our dignity, and as likely to lead to trite consumerism, homogenization, and a Brave New World¹¹⁷. While these fears appear to be triggered less by the prospect of cognitive enhancement than by other possible forms of human enhancement or modification (e.g. of mood and emotion), they do reflect a general unease about making "the essence of human nature" a project of technological mastery¹¹⁸.

To some extent, these are cultural, social, and political issues rather than purely ethical ones. A blinkered pursuit of shallow or misguided ends is not the only way in which enhancement options could be used. If there were a widespread tendency to use the options in that way, then the problem would probably lie in our culture. The criticism is a criticism of mediocrity and bad culture rather than of enhancement tools. Many of the negative consequences of enhancement may be avoided or changed in different social contexts. Critics could argue that we have to look at the culture we have, not some ideal alternative, or that there are particular attributes of the technologies which will inevitably promote the erosion of human values.

Again, however, cognitive enhancements have the potential to play a positive role. Insofar as cognitive enhancements amplify the capacities required for autonomous agency and independent judgment, they can help a person lead a more authentic life by

¹¹⁷ (The President's Council on Bioethics 2003)

¹¹⁸ (Kass 2002)

enabling her to base her choices on more deeply considered beliefs about her unique circumstances, her personal style, her ideals, and the options available to her.

Hyper-agency, playing God, and the status quo

The concern about “hyper-agency” is in a sense opposite to the concern about authenticity. Here, the issue is that as human beings become more able to control their lives and themselves, they also become more responsible for the results and less constrained by traditional limits. The “playing God” objection asserts that human wisdom is insufficient to manage this freedom. Whether hyper-agency is a problem or not depends on both an analysis of the ethical implications of increased agency (such as the burden of responsibility for previously uncontrollable events, and the potential for increased autonomy) and the psychological and sociological question of how humans would in fact react to their increased degrees of freedom, power, and responsibility¹¹⁹. The policy challenge might be to ensure that there are adequate safeguards, regulations, and transparency to support a society of increasingly cognitively resourceful individuals, and also to moderate unrealistic expectations of infallibility.

Another version of the playing God argument asserts that it is sometimes better to respect “the Given” than to try to better things using human abilities¹²⁰. The claim that we should stick with the status quo can be based on a religious sensibility, the idea that we literally risk offending God if we overstep our mandate here on Earth. It can also be based on a less theologically articulated feeling that the proper approach to the world is one of humility and that enhancement would upset the moral or practical order of things; or, alternatively, on an explicitly conservative vision according to which the existing state of affairs has, due to its age, acquired some form of optimality. Since human agency is already interfering with the natural order in many ways that are universally accepted (for example, by curing the sick), and since society and technology have always been changing and often for the better, the challenge for this version of the playing God argument is to determine which particular kinds of interventions and changes would be bad.

One recent paper has examined the extent to which opposition to cognitive enhancement is the result of a status quo bias, defined as an irrational or inappropriate preference for the status quo just because it is the status quo. When this bias is removed, through the application of a method which the authors call “the Reversal Test”, many consequentialist objections to cognitive enhancements are revealed to be highly implausible¹²¹.

¹¹⁹ “In my view, the fear of hyper-agency is misplaced; society as a whole seems always to return to the reasonable use of new knowledge. ... Just as most people don't drink all the liquor in their liquor cabinet...our society will absorb new memory drugs according to each individual's underlying philosophy and sense of self.”, (Gazzaniga 2005)

¹²⁰ (Sandel 2002; Sandel 2004); but see also a critique in (Kamm 2006)

¹²¹ (Bostrom and Ord 2006)

Cheating, positional goods, and externalities

On some campuses it is now not uncommon for students to take Ritalin when preparing for exams (not to mention caffeine, glucose snacks, and energy drinks). Does this constitute a form of cheating akin to illicit doping in the Olympics? Or should students be positively *encouraged* to take performance enhancers (assuming they are sufficiently safe and efficacious) for the same reasons that they are encouraged to take notes and to start revising early?

Whether an action constitutes cheating depends on the agreed game rules for different activities. To pick up the ball with one's hands is cheating in golf and soccer, but not in handball or American football. If school is to be regarded as a competition for grades, then enhancers would arguably be cheating if not everyone had access to enhancements or if they were against the official rules. If school is viewed as having primarily a social function, then enhancement might be irrelevant. But if school is seen as being significantly about the acquisition of information and learning, then cognitive enhancements may have legitimate and useful role to play.

A positional good is one whose value is dependent on others not having it. If cognitive enhancements were purely positional goods, then the pursuit of such enhancements would be a waste of time, effort, and money. People might become embroiled in a cognitive "arms race", spending significant resources merely in order to keep up with the Joneses. One person's gain would produce an offsetting negative externality of equal magnitude, resulting in no net gain in social utility to compensate for the costs of the enhancement efforts.

Most cognitive functions, however, are not purely positional goods¹²². They are also intrinsically desirable: their immediate value to the possessor does not completely depend on other people lacking them. Having a good memory or a creative mind is normally valuable in its own right, whether or not other people also possess similar excellences. Furthermore, many cognitive capacities also have instrumental value, both for individuals and for society. We face many pressing problems which we would be better able to solve if we were smarter, wiser, or more creative. An enhancement that enables an individual to solve some of society's problems would produce a positive externality: in addition to benefits for enhanced individual, there would be spillover benefits for other members of society.

Nevertheless, competitive aspects of enhancements should be taken into account when we assess the impact they might have on society. An enhancement may be entirely voluntary and yet become difficult to avoid for those who do not desire it. It has been suggested that many people would prefer to fly with airlines or go to hospitals where the personnel take alertness-enhancing drugs. Such preferences could expand employment opportunities for those willing to enhance themselves. Economic competition might

¹²² (Bostrom 2003)

eventually force people to use enhancements on pain of rendering themselves ineligible for certain jobs¹²³.

The case might be compared to that of literacy, which is also forced upon citizens in modern societies. For literacy, the enforcement is both direct, in the form of mandatory basic education, and indirect, in the form of severe social penalties for failure to acquire reading and writing skills. The dominant cooperative framework¹²⁴ of our society has developed in such a way that an illiterate person is excluded from many opportunities and unable to participate in many aspects of modern life. Despite these enormous and partially coercive pressures, and despite the fact that literacy profoundly changes the way the brain processes language,¹²⁵ literacy is not regarded as particularly problematic. The costs of illiteracy are placed on the individual who deliberately avoids education. As social acceptance of other enhancements increases, and if these are available at a reasonable price, it is possible that support for people who refuse to take advantage of enhancements will diminish.

Inequality

Concern has been voiced that cognitive enhancements might exacerbate social inequality by adding to the advantages of elites.

To assess this concern one would have to consider whether future cognitive enhancements would be expensive (like good schools) or cheap (like caffeine). One would also have to take into account that there is more than one dimension to inequality. For example, in addition to the gap between the rich and the poor, there is also a gap between the cognitively gifted and the cognitively deficient. One scenario might be that the wealth gap increases at the same time as the talent gap decreases because it is generally easier to enhance individuals at the low end of the performance spectrum than those at the high end (whose brains are already functioning close to their biological optimum). This could add a degree of complexity that is often overlooked in the ethical literature on inequality. One should also have to consider under what conditions society might have an obligation to ensure universal access to interventions that improve cognitive performance. An analogy might be drawn to public libraries and basic education¹²⁶. Other relevant factors include the speed of technology diffusion, the need for education to achieve full utilization of an enhancement, regulatory approach, and accompanying public policies. Public policy and regulations can either contribute to inequality by driving up prices, limiting access, and creating black markets; or reduce inequality by supporting broad development, competition, public understanding, and perhaps subsidized access for disadvantaged groups.

Different kinds of enhancements pose different social challenges. A pill that slightly improves memory or alertness is a very different thing than some future radical form of

¹²³ (Chatterjee 2004)

¹²⁴ (Buchanan, Brock et al. 2001)

¹²⁵ (Petersson, Reis et al. 2000)

¹²⁶ (Hughes 2004)

genetic engineering that could lead to the creation of a new “posthuman” human species¹²⁷. It has been argued that even very powerful enhancements could be placed within a regulatory framework for leveling the playing field if the objective is seen as important enough¹²⁸, but whether the political will to do so will be forthcoming remains to be seen.

It is worth noting that inequality of access to enhancement is a pressing concern only if we agree that enhancement confers genuine benefits. Otherwise, as Leon Kass observes, complaining about unequal access to enhancement would be equivalent to objecting that “the food is contaminated, but why are my portions so small?”¹²⁹

IV. Discussion: challenges for regulation and public policy

“Conventional” means of cognitive enhancement, such as education, mental techniques, neurological health, and external systems, are largely accepted, while “unconventional” means – drugs, implants, direct brain-computer interfaces – tend to evoke moral and social concerns. However, the demarcation between these two categories is blurry. It might be the newness of the unconventional means, and the fact that they are currently still mostly experimental, which is responsible for their problematic status rather than any essential problem with the technologies themselves. As we gain more experience with currently unconventional technologies, they may become absorbed into the ordinary category of human tools.

At present, most biomedical enhancement techniques produce at most modest improvements of performance (as a rule of thumb, about 10-20% improvement on typical test tasks). More dramatic results can be achieved using training and human-machine collaboration, techniques that are less controversial. Mental techniques can achieve 1000% or more improvement in narrow domains such as specific memorization tasks¹³⁰. While pharmacological cognitive enhancements do not produce dramatic improvements on specific tasks, their effects are often quite general, enhancing performance across a wide domain, such as all tasks making use of working memory or long term memory. External tools and cognitive techniques such as mnemonics, in contrast, are usually task-specific, producing potentially large improvements of relatively narrow abilities. A combination of different methods can be expected to do better than any single method, especially in everyday or workplace settings where a wide variety of tasks have to be performed.

Even small improvements in general cognitive capacities can have important positive effects. Individual cognitive capacity (imperfectly estimated by IQ scores) is positively correlated with income. One study estimates the increase in income from one additional

¹²⁷ (Silver 1998) (Fukuyama 2002)

¹²⁸ (Mehlman 2000)

¹²⁹ (Kass 2003), p. 15.

¹³⁰ (Ericsson, Chase et al. 1980)

IQ point to 2.1% for men and 3.6% for women¹³¹. Higher intelligence appears to prevent a wide array of social and economic misfortunes¹³² and to promote health¹³³. Economic models of the loss caused by small intelligence decrements due to lead in drinking water predict significant effects of even a few points change¹³⁴, and it is plausible that a small *increment* would have positive effects of a similar magnitude. At a societal level, the consequences of many small individual enhancements may be profound. A relatively small upward shift of the distribution of intellectual abilities would substantially reduce the incidence of retardation and learning problems. Such a shift would likely also have important effects on technology, economy, and culture arising from improved performance among high IQ groups.

Many extant regulations are intended to protect and improve cognitive function. Regulation of lead in paint and tap water, requirements of boxing, bicycle, and motorcycle helmets, bans on alcohol for minors, mandatory education, folic acid fortification of cereals, and sanctions against mothers who abuse drugs during pregnancy all serve to safeguard or promote cognition. To a large extent, these efforts are a subset of general health protection measures, yet stronger efforts appear to be made when cognitive function is at risk. One may also observe that mandated information duties, such as labelling of food products, were introduced to give consumers access to more accurate information in order to enable them to make better choices. Given that sound decision-making requires both reliable information and the cognitive ability to retain, evaluate, and apply this information, one would expect that enhancements of cognition would promote rational consumer choice.

By contrast, we know of no public policy that is intended to limit or reduce cognitive capacity. Insofar as patterns of regulation reflect social preferences, then, it seems that society shows at least an implicit commitment to better cognition.

At the same time, however, there exist a number of obstacles to the development and use of cognitive enhancements. One obstacle is the present system for licensing drugs and medical treatments. This system was created to deal with traditional medicine which aims to prevent, diagnose, cure, or alleviate disease. In this framework, there is no room for enhancing medicine. For example, drug companies could find it difficult to get regulatory approval for a pharmaceutical whose sole use was to improve cognitive functioning in the healthy population. To date, every pharmaceutical on the market that offers some potential cognitive enhancement effect was developed to treat some specific pathological condition (such as ADHD, narcolepsy, and Alzheimer's disease). The cognitive enhancing effects of these drugs in healthy subjects is a serendipitous unintended effect. Progress in this area might be accelerated if pharmaceutical companies could focus directly on developing nootropics for use in non-diseased populations rather than having

¹³¹ (Salkever 1995)

¹³² (Gottfredson 1997; Gottfredson 2004). There is no link between higher intelligence and more happiness (Sigelman 1981; Hartog and Oosterbeek 1998; Gow, Whiteman et al. 2005). However, see also (Newson 2000) for some more subtle ways intelligence might bring happiness.

¹³³ (Whalley and Deary 2001)

¹³⁴ (Salkever 1995) (Muir and Zegarac 2001)

to work indirectly by demonstrating that the drugs are also efficacious in treating some recognized disease.

One of the perverse effects of the failure of the current medical framework to recognize the legitimacy and potential of enhancement medicine is the trend towards medicalization and “pathologization” of an increasing range of conditions that were previously regarded as part of the normal human spectrum. If a significant fraction of the population could obtain certain benefits from drugs that improve e.g. concentration, it is currently necessary to categorize this segment of people as having some disease – in this case attention-deficit hyperactivity disorder – in order to get the drug approved and prescribed to those who could benefit from it. This disease-focused medical model is increasingly inadequate for an era in which many people will be using medical treatments for enhancement purposes.

The medicine-as-treatment-for-disease framework creates problems not only for pharmaceutical companies but also for users (“patients”) whose access to enhancers is often dependent on being able to find an open-minded physician who can prescribe the drug. This creates inequities in access. People with high social capital and good information get access while others are excluded.

The rise of personalized medicine which we are now beginning to see results both from improved diagnostic methods that provide a better picture of the individual patient and from the availability of a wider range of therapeutic options which make it necessary to select the one that is most suitable for a particular patient. Many patients now approach their physicians armed with detailed knowledge about their condition and possible treatments. Information can be easily obtained from Medline and other Internet services. These factors are leading to a shift in the physician-patient relationship, away from paternalism to a relationship characterized by teamwork and a focus on the customer’s situation. Preventative and enhancing medicine are often inseparable, and both will likely be promoted by these changes and by an increasingly active and informed health care consumer who insists on exercising choice in the medical context. These shifts suggest the need for important and complex regulatory change.

Given that all medical interventions carry some risk, and that the benefits of enhancements may often be more subjective and value-dependent than the benefits of being cured of a disease, it is important to allow individuals to determine their own preferences for tradeoffs between risks and benefits. It is highly unlikely that one size will fit all. At the same time, many will feel the need for a limited degree of paternalism, to protect individuals from at least the worst risks. One option would be to establish some baseline level of acceptable risk in allowable interventions, perhaps by comparison to other risks that society allows individuals to take, such as the risks from smoking, mountain climbing, or horseback riding. Enhancements that could be shown to be no more risky than these activities would be allowed (with appropriate information and warning labels when necessary). Another possibility would be enhancement licenses. People willing to undergo potentially risky but rewarding enhancements could be required to demonstrate sufficient understanding of the risks and the ability to handle

them responsibly. This would both ensure informed consent and enable better monitoring. A downside with enhancement licenses is that people with low cognitive capacity, who may have the most to gain from enhancements, could find it hard to get access if the license requirements were too demanding.

Public funding for research does not yet reflect the potential personal and social benefits of many forms of cognitive enhancement. There is funding (albeit perhaps at inadequate levels) for research into education methods and information technology, but not for pharmacological cognitive enhancers. In view of the potentially enormous gains from even moderately effective general cognitive enhancements, this area deserves large-scale funding. It is clear that much research and development are needed to make cognitive enhancement practical and efficient. As discussed above, this requires a change of the view that medicine is only about restoring, not enhancing, capacities, and concomitant changes in the regulatory regime for medical trials and drug approval.

The evidence on prenatal and perinatal nutrition suggests that infant formulas containing suitable nutrients may have a significant positive life-long impact on cognition. Because of the low cost and large potential impact of enriched infant formula if applied at a population level, it should be a priority to conduct more research to establish the optimal composition of infant formula. Regulation could then be used to ensure that commercially available formula contains these nutrients. Public health information campaigns could further promote the use of enriched formula that promote mental development. This would be a simple extension of current regulatory practice, but a potentially important one.

There is a wider cultural challenge of destigmatizing the use of enhancers. At present, the taking of medicine is regarded as a regrettable condition, and use of non-therapeutic medication is seen as suspect, possibly misuse. Attempts to enhance cognition are often construed as expression of a dangerous ambition. Yet the border between accepted therapy and suspect enhancement is shifting. Pain relief is now seen as unproblematic. Plastic surgery enjoys ever-wider acceptance. Millions of people ingest nutrient supplements and herbal remedies for enhancing purposes. Self-help psychology is very popular. Apparently, the cultural constructions surrounding the means of enhancement are more important for their acceptance than the actual enhancement ability of these means. To make the best use of our new opportunities, we need a culture of enhancement, with norms, support structures, and a lay understanding of enhancement that takes it into the mainstream cultural context. Consumers also need better information on risks and benefits of enhancers, which suggests a need for reliable consumer information and for more studies to determine safety and efficacy.

Testing of cognitive enhancers would ideally be done not only in the lab but also in field studies that investigate how an intervention works in everyday life. The ultimate criterion of efficacy would be various forms of life success rather than performance in a narrow psychological lab tests. Such “ecological testing” would require new kinds of experiment, including monitoring of large sample populations. Advances in wearable computers and sensors may allow unobtrusive monitoring of behavior, diet, use of other drugs, etc. Data

mining of collected materials could help determine the effects of enhancers. Such studies, however, would pose major challenges, including cost, new kinds of privacy concerns (monitoring may accumulate information not only about the consenting test subjects but also about their friends and family), and problems of unfair competition if enhancers experience beneficial effects but others cannot get access to the enhancements due to their experimental nature.

While access to medicine is currently regarded as a human right constrained by cost concerns, it is less clear whether access to all enhancements should or would be regarded as a positive right¹³⁵. The case for at least a negative right to cognitive enhancement, based on cognitive liberty, privacy interests, and the important interest of persons to protect and develop their own minds and capacity for autonomy, seems very strong¹³⁶. Banning enhancements would create an incitement for black markets as well as limit socially beneficial uses. Legal enhancement would promote development and use, in the long run leading to cheaper and safer enhancements. Yet without public funding, some useful enhancements may be out of reach for many of the people who would benefit the most from them. Proponents of a positive right to enhancements could argue for their position on grounds of fairness or equality, or on grounds of a public interest in the promotion of the capacities required for autonomous agency. The societal benefits of effective cognitive enhancement may even turn out to be so large and clear that it would be Pareto optimal to subsidize enhancement for the poor just as the state now subsidizes education.¹³⁷

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¹³⁵ For an argument that it should, see (Hughes 2004)

¹³⁶ It can certainly be argued as a negative right, cf. (Boire 2001; Sandberg 2003)

¹³⁷ We are grateful to Rebecca Roache for helpful comments on an earlier version of this paper.

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